Chapter 2

Introduction

This report documents the process and procedures used to evaluate the cost effectiveness of including infiltration/inflow (I/I) reduction projects as part of King County's conveyance system improvement (CSI) program, as called for in the Regional Wastewater Services Plan (RWSP). The CSI program identified a list of capital facility improvements that are needed to accommodate the increasing levels of wastewater flows due to changing conditions in the regional service area. One of these changes is the escalating level of I/I that enters the regional conveyance system during wet weather periods.

Figure 2-1 shows the major sources of I/I. The box below includes definitions of *infiltration* and *inflow*. To provide a consistent basis for comparing the benefits and costs of I/I reduction projects to the benefits and costs of CSI projects, data from wastewater system flow monitoring, hydrologic and hydraulic models, and pilot I/I reduction projects were collected and assumptions were developed. A database-driven benefit/cost analysis tool was developed and used to analyze these data and assumptions and to identify candidate cost-effective I/I reduction projects for additional review and consideration. Candidate I/I reduction projects were considered cost effective when the total estimated CSI project savings after I/I reduction was greater than the total estimated cost of the I/I reduction.

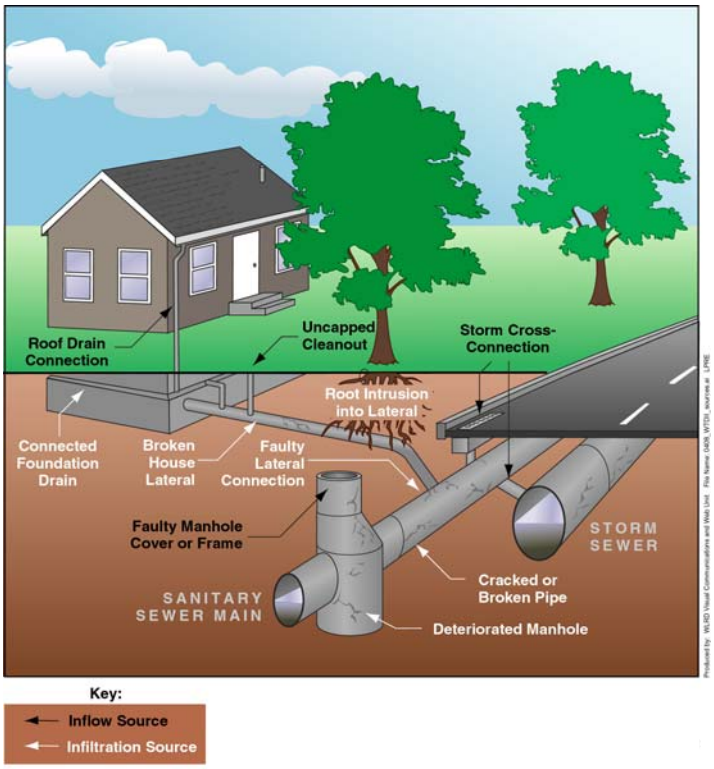

Figure 2-1. Sources of Infiltration and Inflow

Infiltration is subsurface flow, or groundwater, that seeps into sewers through holes, breaks, joint failures, defective connections, and other openings. Infiltration can occur throughout the year, but volumes are typically greater after large storms or prolonged wet weather periods.

Inflow is storm-related surface water that enters the sewer system via roof downspouts, yard and shallow foundation drains, catch basins, leaking manhole covers, and other sources.

Figure 2-1 shows the sources of infiltration and inflow.

2.1 Background

In December 1999, the King County Council approved the development of a Regional I/I Control Program as part of the RWSP. The purpose of the program is to reduce the risk of sanitary sewer overflows and the cost of adding capacity to facilities that convey wastewater to County treatment plants.

In 2000, the County's Wastewater Treatment Division, in cooperation with the local component agencies that it serves, launched the 6-year I/I control study. The study included efforts to identify sources and quantities of I/I within the regional service area, test the effectiveness of various I/I control technologies to reduce I/I, examine the benefits and costs of implementing I/I reduction measures, and prepare a regional plan for reducing I/I in local agency collection systems.

The benefit/cost analysis was completed in July 2005. The results of the analysis were incorporated into the *Executive's Preferred Plan* for reducing I/I in the County service area.

2.1.1 Regional System

The County's regional wastewater system serves approximately 1.4 million residents within a 420-square-mile service area encompassing portions of King, Snohomish, and Pierce counties. It is a large, integrated wastewater collection, conveyance, and treatment system operated by the County and 34 cities and local sewer districts collectively referred to as the local agencies. The regional conveyance system includes pipes, pump stations, and other facilities that were built as early as 1900, and substantial additions remain underway. Design standards and growth projections change over time, and this is reflected in various portions of the conveyance system.

Historically, conveyance and treatment facilities in the County service area have experienced significant I/I flows during the October-to-March wet season. I/I has a significant impact on the capacity of the regional wastewater conveyance and treatment systems because it is the largest contributor to the wastewater volumes that must be conveyed and treated during the wet season. Approximately 75 percent of the region's peak flows in the separated conveyance system is from I/I[1]. This additional volume due to I/I requires the County to develop and provide increased wastewater conveyance and treatment capacity in order to remain in compliance with regulatory agency requirements and permitting. This requires that conveyance system pipelines and treatment plants be built large enough to accommodate the high flows resulting from I/I even though this maximum capacity is not needed all the time. Updated capacity assessments and projected new conveyance facility needs were developed as part of the Regional Needs Assessment and are summarized in Section 3.2.4.9 and Table 3-12[2].

[1] *Regional Wastewater Services Plan, Executive's Preferred Plan*; April 1998, Page 14.
[2] For more detailed information about projected conveyance facility needs, see the *Regional Needs Assessment Report* (March 2005).

2.1.2 Local Agency Systems

Approximately 95 percent of the I/I discharging to the regional conveyance and treatment systems originates in collection systems owned by the local agencies and from the residents and businesses they serve. Approximately 50 percent of the I/I contributed from the local agencies is estimated to come from leaks and cracks in the sewer lines and roof drains that connect homes and businesses to local agency sewers[3]. In order to collect and develop the data needed to complete the benefit/cost analysis, an extensive effort was undertaken to locate and quantify I/I within the local agency systems and the regional conveyance service area.

The local agencies provide direct sewer collection service to the residences and businesses within their service areas. Local agency facilities include collector sewers, laterals, side sewers, and some pump stations. Private property owners typically own the side sewer pipes that connect their property to the local agency collection pipes. The total length of all local agency sewer lines that are designed to carry only sewage (separated system) in the County's service area is approximately 17.5 million feet and does not include the local agency sewers that are designed to carry both sewer and clean, storm-generated flows (combined system).

2.2 Data Needed for the Benefit Cost Analysis

Data for the Regional I/I Control Program was collected between 2000 and 2005. Data collected and developed early in the program (rainfall and flow monitoring data) provided the foundation for subsequent decision-making processes (for example, hydrologic and hydraulic modeling, and pilot project selection). In turn, these processes provided information for completing the Regional Needs Assessment, for constructing 10 pilot projects, and for evaluating alternatives and options for I/I reduction. The benefit/cost analysis was based on information obtained from these earlier efforts.

The local agencies were actively involved in developing and evaluating I/I Control Program data and milestones. This included local agency involvement in developing the assumptions, costs, and I/I reduction factors that were used in the benefit/cost analysis. Brief descriptions of the data sources are provided below with references to additional supporting documentation.

Local Agency Collection System Characteristics

A coordinated County and local agency effort identified the physical locations and characteristics (size, age, material) of local agency collection systems, property boundaries, and topography. This information was needed to subdivide the service area into mini-basins and model basins[4] for flow monitoring and modeling. The information was ultimately needed to investigate the correlation between sewer pipe age, materials, and quantity of I/I within a local agency collection

[3] *Brightwater Final Environmental Impact Statement*, Section 2.3.2, Page 2.12.
[4] *Mini-basins*, containing an average of 22,000 linear feet of sewer lines, provided manageable target areas for sewer system evaluation and rehabilitation. *Model basins*, containing an average of 1,000 sewered acres and 100,000 linear feet of pipe, facilitated modeling of I/I and sewage flows.

system. Additional information related to local agency collection system characteristics can be found in Section 3.2.1[5] of this Report.

Rainfall Monitoring and Modeling

Enhanced rainfall data for the I/I program was developed by using multiple rainfall recording stations to calibrate a radar-based rainfall technology called CALAMAR (*calcul de lames d'eau a l'aide du radar*, which translates from French as "calculating rain with the aid of radar"). The CALAMAR rainfall model was used to establish the amount of rainfall that occurred over specific geographic areas that coincided with the mini-basin and model basin configurations and the measured changes in wastewater flows during rainfall events. Additional information related to the development, calibration, and use of the CALAMAR is provided in Section 3.2.2.

Flow Monitoring

Based on the mini-basin and model basin boundaries established by the County, flow meters were installed in local agency sewer pipes during two consecutive wet weather flow periods to: (a) establish the amount of sewer flow that came from each geographic area, and (b) measure the changes in these flows when rainfall occurred. Measuring the changes in wastewater flows during rainfall events was necessary to quantify the volume of I/I originating from the specific geographic areas. A more detailed description of flow monitoring is included in Section 3.2.3.

Flow Modeling

The County utilized hydrologic and hydraulic models[6] to simulate the performance of local agency wastewater collection and County conveyance systems. These models were used to simulate sewer flows generated from each of the local agency systems and from model basins and mini-basins. Sewer flow models were developed for existing and future development conditions and also provided the estimated I/I flow quantities under these two conditions. The quantities of projected I/I flows from each modeled source was used to evaluate the flow capacity of the existing County conveyance and treatment facilities and to identify the location and extent of additional capacity requirements. This provided the basis for selecting the I/I reduction techniques used in the benefit/cost analysis. A more detailed description of the hydrologic and hydraulic modeling effort is provided in Section 3.2.4.

Planning Assumptions

To provide consistency between the planning variables common to the CSI projects and I/I reduction projects, planning assumptions were developed and accepted for use by the County and local agencies. These assumptions included, but were not limited to:

[5] For more detailed information about the characteristics of local agency collection systems and the other topics in this section, see the *2000/2001 Wet Weather Flow Monitoring Technical Memorandum* (May 2001).
[6] The *hydrologic model* was used to numerically simulate the physical process of how rainfall ends up as I/I. The *hydraulic model* was used to simulate the pipes that convey wastewater flows and the I/I generated by the hydrologic model.

- The rate at which new sewer connections take place
- The rate at which the existing and aging sewer collection system allows entry of increasing amounts of I/I
- The impact of water conservation on sewer conveyance system capacity and future needs
- Financial variables that may impact inflation and lending costs
- Financial variables that directly impact both I/I reduction and CSI project costs (for example, utility conflicts, traffic control, sales tax, contingency costs, project costs related to environmental or public impacts, and allied costs[7])[8]

Regional Needs Assessment

Based on the information developed from the hydrologic and hydraulic models, a conveyance system capacity assessment was completed to identify the need for additional conveyance system improvement (CSI) projects. The existing County conveyance system hydraulic model was utilized to analyze the capacity of the existing County conveyance system and to establish the extent of required capacity improvements. The County cost estimating model (referred to as TABULA) was used to estimate the costs associated with planning, design, and construction of the additional CSI projects. This list of CSI projects provided the baseline for conducting benefit/cost analysis of potential I/I reduction projects. As stated earlier, I/I reduction projects were considered cost effective when the total estimated CSI project savings after I/I reduction was greater than the total estimated cost of the I/I reduction. Additional information about the Regional Needs Assessment, including a summary list of needed CSI projects and costs is included in Section 3.2.4.9[9] of this Report.

Pilot Projects

The results and lessons learned from 10 pilot projects demonstrated the County's level of success in finding and reducing I/I through physical inspection of sewer collection pipes. The pilot projects also provided the opportunity to compare cost estimates developed during each project's design phase with the bid and final construction costs. The effectiveness of a variety of I/I rehabilitation methods (for example, dig and replace, pipe bursting, cured-in-place lining) was evaluated through the use of flow monitoring and hydrologic modeling conducted before (pre-rehabilitation) and after (post-rehabilitation) completing pilot project construction. The construction, flow monitoring, and modeling results from the pilot projects defined a combination of potential I/I reduction techniques that could be used for evaluating the cost effectiveness of I/I reduction. This information provided a starting point for developing the I/I rehabilitation assumptions used in the benefit/cost analysis. Additional information about the locations of the 10 pilot projects, the techniques selected for I/I reduction, and the use of the

[7] Allied costs are those project costs associated with planning, predesign, design, construction, closeout, land acquisition, and other non-construction contingency.
[8] For more information about the development of planning assumptions, see Appendix A4 of the *Alternatives/Options Report* (March 2005).
[9] For more information about the process used to evaluate the County conveyance system and to determine the extent of needed conveyance projects, see the *Regional Needs Assessment Report* (March 2005).

hydrologic model and post-rehabilitation flow monitoring is included in Section 3.2.5[10] of this Report.

I/I Rehabilitation Assumptions

The estimated quantity of work, total cost, and I/I reduction achieved from each selected I/I reduction technique was developed and agreed-to through a County/local agency consensus process, and lead to the identification of alternatives and options for achieving I/I reduction. At the request of the local agencies, another set of rehabilitation assumptions was utilized in completing a Sensitivity Analysis of the output of the benefit/cost analysis. Additional information related to the values used for planning assumptions is included in Section 3.2.5.3 of this Report.

I/I Reduction Techniques

I/I reduction techniques[11] developed for use in the benefit/cost analysis provided a full range of responses to different identified sources of I/I. These techniques could be implemented on public or private property and could include reduction of inflow sources alone, infiltration and inflow in combination, or infiltration only. Information about the development of the I/I reduction techniques utilized in the benefit/cost analysis are included in Section 3.2.5.3 and Table 3-5 of this Report.

I/I Reduction Technique Selection

A series of threshold values for selecting four possible I/I reduction techniques was developed to allow an expedited database analysis for each I/I reduction project included in the benefit/cost analysis. The threshold values and method for selecting the initial I/I reduction technique are included in Section 3.2.5.3 and Figure 3-11 of this Report.

As the collection and development of the data sources described above evolved, each completed data source served as a checkpoint for or validation of the previously developed data. In some cases, previously developed data was revisited and confirmed prior to continuing with the next step of the analysis. Ultimately, each of the data sources was either instrumental to the development of data used in the benefit/cost analysis or was itself used to complete the analysis. Figure 3-1 shows how the numerous data sources were used in the benefit/cost analysis.

[10] For more information about pilot project selection, design, construction, I/I reduction effectiveness, costs, and lessons learned, see the *Pilot Project Report* (October 2004).

[11] *I/I reduction technique* refers to a means of decreasing I/I by replacing or rehabilitating selected components of the sewer system (for example, replacing public sewers and direct disconnects of downspouts). *I/I rehabilitation method* refers to the technology used to repair sewer system components (for example, dig and replace, pipe bursting, slip lining).

2.3 Benefit/Cost Analysis Tool

The Benefit/Cost Analysis Tool (B/C Tool) described in Section 4.2 helped the County evaluate I/I reduction as an alternative to building new or larger CSI projects. The B/C Tool provided information for determining the optimal I/I reduction available for eliminating or downsizing a proposed conveyance system facility improvement.

2.4 Alternatives for Evaluating Benefit/Cost

Once all the associated data were collected and developed, analysis of the alternatives and options provided direction about how the data could be evaluated. The *Alternatives/Options Report* describes various I/I program alternatives, including alternatives that focus on I/I reduction projects with benefits equal to or greater than the costs of improving regional capital facilities. The local agencies agreed that the three alternatives for evaluating benefits and costs would include the following (see Section 3.2.6 for more information about alternatives):

- The estimated benefits and costs of reaching the 30-percent I/I reduction goal as it was described in the *Regional Wastewater Services Plan* (RWSP)
- The estimated benefits and costs for I/I reduction projects that are found to be cost effective on a region-wide basis (re-investing all I/I reduction savings from cost-effective projects into additional I/I reduction projects until the savings are exhausted)
- The estimated benefits and costs for I/I reduction projects that are found to be cost effective on a project-specific basis (evaluating the costs and benefits of each planned conveyance facility on its own merits)

For more detailed explanation of the three alternatives, see the March 2005 *Alternatives/Options Report*, and the attached appendices:

- Appendix A1 - Select List Cost-Effectiveness Analysis Package per MWPAAC E&P Planning Assumptions
- Appendix A2 - Regional Cost Effectiveness Analysis Package per MWPAAC E&P Planning Assumptions
- Appendix A3 - 30-Percent I/I Removal Cost Effectiveness Package per MWPAAC E&P Planning Assumptions
- Appendix B1 - Sensitivity Analysis Select List-Cost Effectiveness Analysis Packages per Initial Planning Assumptions